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Kinetics of Capture and Translocation in Salt Asymmetry

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Solid-state nanopores can be used as single-molecule detection devices. Since the rate of passage through a nanopore is proportional to the polyeletrolyte concentration, solid-state nanopores can be used to precisely quantify dilute concentrations (nM/pM) of disease-relevant biomarkers. Accurate concentration measurements require statistically significant sample sizes of translocation events, meaning that low abundance biomarkers require significantly longer experiments. A difference in salt concentration on either side of the nanopore (salt asymmetry) can be used to offset this effect by increasing the capture rate without increasing translocation speed (current trace resolution does not suffer), effectively lowering the concentration limit of detection. Therefore, it is of great interest to study the kinetics of capture and translocation by solid-state nanopores in salt asymmetry. The capture rate dependence on the salt concentration ratio, on applied voltage, and on DNA length, is used to infer a transition between two distinct capture rate scaling regimes in salt asymmetry. In the diffusion-limited regime capture rate increases linearly with the salt concentration ratio while in the barrier-limited regime capture rate increases super-linearly with the salt concentration ratio. We show that salt concentration ratios promoting capture shift the transition points dividing regimes, further increasing the range of diffusion-limited capture, a requirement for precise nanopore concentration measurements via Controlled Counting (https://doi.org/10.1021/acs.analchem.9b01900). In terms of translocation kinetics, we report a smaller scaling exponent relating DNA length to translocation event duration in salt asymmetry compared to the analogous exponent in symmetric salt, and show that salt asymmetry promotes folded translocations. Finally, we provide experimental evidence which supports tension propagation theory, providing insight into the sampled polymer conformations during the non-equilibrium translocation process.

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